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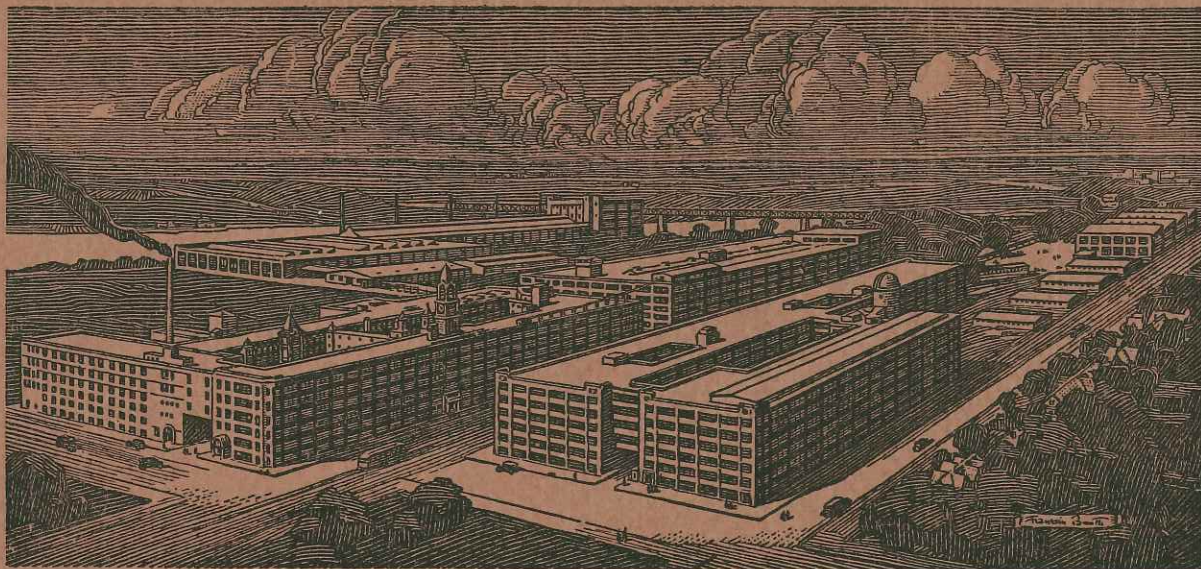
CATALOG D-221

SEP 9 - 1939

Bausch & Lomb
SPECTROMETRIC
EQUIPMENT

D571E





Multiplying *Seeing* Power

THE progress of civilization has followed the path of light. To men of science, optical instruments are taken as a matter of course, and properly so, since a modest master deserves a modest servant.

There is another application of optics less spectacular than the microscope, the photographic lens, the spectrograph, and the host of special instruments with which it has been the privilege of the Bausch & Lomb Optical Co. to serve Science, Industry and Education.

Defective sight, congenital or acquired through use or abuse, disease and age, is one of the commonest physical failings. From its beginning in 1853, Bausch & Lomb has engaged in continuous research devoted to the correction and amelioration of this universal handicap.

From the Ophthalmic Division of Bausch & Lomb have come such notable contributions as the Orthogon series of Corrected Lenses, Panoptik Bifocals, Loxit Mountings, Nokrome Glass, and a wide variety of Ophthalmic Instruments. These have helped the oculist, optometrist and optician to improve their procedures. They specify and furnish more than twenty millions of Bausch & Lomb eyeglass lenses a year which are used in multiplying seeing power for the masses.

In this way, to both the "man on the street" and the "man in the laboratory," the ideals of the founders, that human vision be conserved and extended, are being more fully realized.



The illustrations in this catalog show Bausch & Lomb scientific instruments of current production. However, due to our constant efforts to improve and refine, this company reserves the right to supply apparatus that may differ in unimportant or minor details from those shown in the illustrations.

SPECTROMETRIC EQUIPMENT



BAUSCH & LOMB
OPTICAL COMPANY - - - ROCHESTER, N. Y., U. S. A.



Basic Theory and Design

A spectrometer or spectrograph is an instrument designed to break up the light from a source into its constituent wavelengths and to provide a means of qualitative or quantitative study of the spectrum thus formed. Basically all designs consist essentially of four parts: (1) the slit, (2) the lenses, (3) the dispersing system, (4) the observing or recording system. Various optical and mechanical arrangements of these units are used, depending on the purpose for which the particular instrument is designed, and it will be of advantage to study these units individually before studying the various combinations.

Slit Design and Construction

Any spectrometer or spectrograph, if it is to function properly, requires that the slit be well made. Generally speaking, in present day practice, the slit is formed of two metal jaws operated by some mechanism which will cause either one or both to move on a line perpendicular to the edge of the jaw. The essential requirements of a good slit may be briefly listed. (1) The two edges must be always parallel to each other. (2) The edges must be sharp and straight. (3) The material of which the slit is made must resist

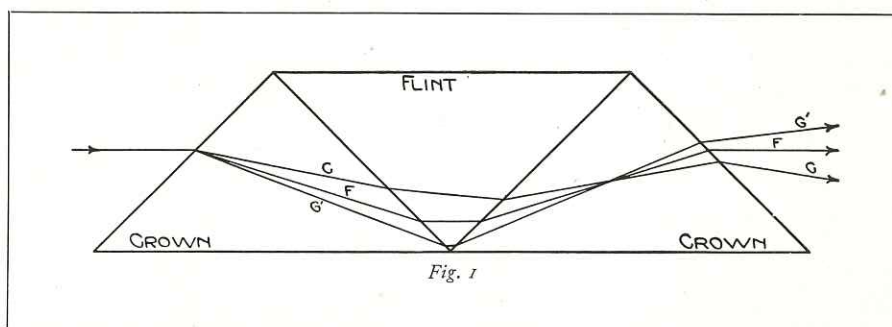
corrosion. (4) The slit must be readily adjustable. Whether it be bilateral or unilateral and with or without a micrometer drum for reading width, will depend mainly on the cost and type of the instrument.

The lens system in all instruments, with the exception of the small hand types, consists of a collimator lens and a telescope or camera lens. The slit is placed in the focal plane of the collimator and the recording or observing system in the focal plane of the telescope lens. Between the two lenses, that is, in the region where the beam is parallel, is placed the dispersing system. If the lenses consist of single elements, their chromatic aberration will cause the various lines or regions of the spectrum to be imaged at different points along the axis. The image in violet light will be formed nearest

the telescope lens and that in red light will be formed furthest from the lens.

Focal Adjustment for Wave Length

When the spectrum is being observed visually, this will mean that the eyepiece must be moved inward as we pass from the red end of the spectrum to the violet. When the spectrum is to be photographed, it will mean that the recording plate must be tilted at an angle in order to bring the entire spectrum into focus at once. With the present available glasses this disadvantage may be partially corrected by the use of achromatic lenses. Such lenses are computed to bring the C and F lines of hydrogen and the D line of sodium into a plane perpendicular to the axis of the instrument. Under



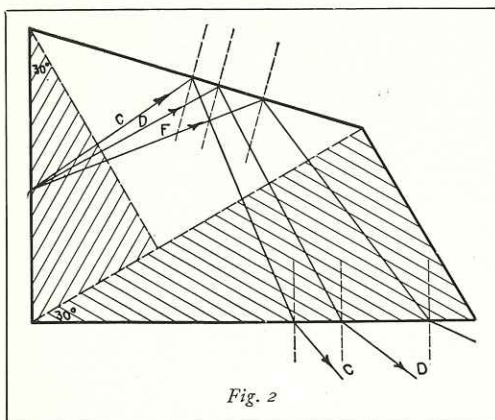


Fig. 2

these conditions slight residual aberration, especially in the violet, will make necessary only slight adjustments as one passes thru the spectrum. In the case where an instrument is used specifically for photographic purposes, the chromatic aberration is disregarded and the available lens surfaces are used to correct other defects of imagery, such as spherical aberration and coma. The plate is then allowed to tilt at a sharp angle to the axis to compensate for chromatic aberration.

Dispersing System

Various types of instruments use different dispersing systems. For the simplest direct vision spectroscopes there is used a cemented prism of the Amici type (Fig. 1) which is normally composed of one flint unit and two crown units, the angles and glass being so chosen that the F line of hydrogen is undeviated. This type of prism makes for a very simple mechanical design in that all the units may be mounted in the same straight line. Its chief disadvantages are that the dispersion is small and that to secure high light gathering power the prisms must be large and cumbersome. Consequently this design is used only in small hand instruments of the qualitative type.

The 60° Prism

The second type of prism is the sixty degree equiangular design, so mounted that the collimator is fixed

and the telescope rotates about the prism axis, its position being read on a divided circle. This type, while advantageous for much simple spectroscopic work, is subject to the disadvantage that it is difficult to use in connection with other pieces of apparatus, since the telescope must be moved when it is desired to change wavelength.

Constant Deviation Types

To overcome the last mentioned defect, prisms of the constant deviation type have been designed. The one most commonly used for the visible region is the Pellin-Broca. It consists essentially of two thirty degree refracting prisms combined with a totally reflecting prism. Figure 2 shows this prism and the path of light through it. The dotted lines indicate the thirty degree prisms and the reflecting prism. In practice it is made from a single piece of glass.

The Thollon Prism

Figure 3 shows another constant deviation type, the Thollon prism. The rotation of either of these prisms about the indicated center maintains a condition of minimum deviation, while at the same time causing the spectrum to move across the field of the eyepiece. From a mechanical point of view this means that a constant angular position may be maintained between the collimator and the telescope, thus providing an instrument which is easily usable in combination with other apparatus.

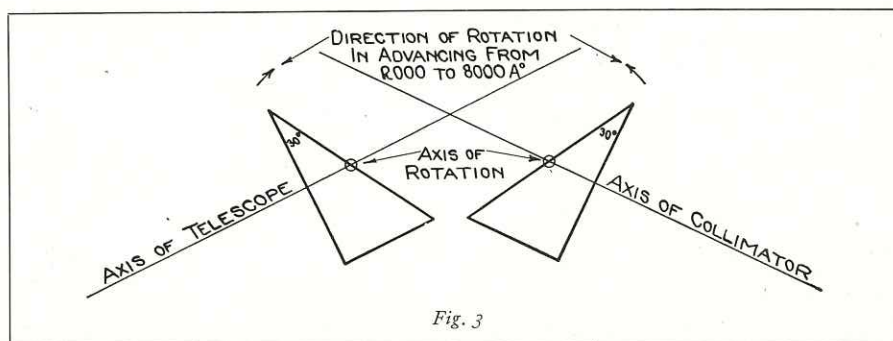


Fig. 3

Recording and Observing

The recording or observing mechanism of the various types needs little explanation. If the instrument is designed for visual observation, it is equipped with a cross hair and eye piece. If a permanent photographic record is desired, the eyepiece is replaced by a plate holder equipped with an operating mechanism. This method is used almost exclusively in the region of the ultra-violet, and in the case of the better visual instruments the design is such that the telescope can be replaced by a camera.

Instrument Design

Certain inherent characteristics which depend on the design of the instrument determine its efficiency. Chief among these are *dispersion* and *resolving power* and before we proceed with the description of the individual models we propose to review briefly the mathematical data on which each is based, in order that we may apply it to each model and thus secure a complete picture of the instrument and its possibilities.

Dispersion

The *dispersion* of any instrument of the spectrometric type is defined as the ratio of the change in the deviation to the change in wavelength and is expressed by the mathematical

form $\left(\frac{d\theta}{d\lambda}\right)$. It depends on the refract-

ing angle of the prism and the nature of the medium used. Since deviation

depends on and varies with index and index varies with wavelength, we may write

$$\frac{d\theta}{d\lambda} = \frac{\delta\theta}{\delta n} \cdot \frac{\delta n}{\delta\lambda}$$

The ratio $\left(\frac{\delta\theta}{\delta n}\right)$ can be determined algebraically and for a prism of sixty degrees reduces finally to

$$\frac{\delta\theta}{\delta n} = \frac{1}{\sqrt{1 - \frac{n^2}{4}}}$$

where (n) is the refractive index of the medium. The second partial $\left(\frac{\delta n}{\delta\lambda}\right)$ is found by the differentiation of the Hartmann formula,

$$\lambda = \lambda_0 + \frac{c}{(n - n_0)}$$

$$\frac{\delta n}{\delta\lambda} = - \frac{c}{(\lambda - \lambda_0)^2}$$

The equation thus becomes

$$\frac{d\theta}{d\lambda} = \left(\frac{1}{\sqrt{1 - \frac{n^2}{4}}}\right) \left(- \frac{c}{(\lambda - \lambda_0)^2}\right)$$

The values for (c) , (λ_0) (λ) and (n_0) can be determined quite easily if the indices for three points are known. When these constants are known the

relation $\left(\frac{d\theta}{d\lambda}\right)$ is determined,

$$\frac{d\theta}{d\lambda} = A.$$

For any value of $(d\lambda)$, as, for instance, the difference of wavelength between the sodium lines, (6×10^{-8}) the corresponding value of $(d\theta)$ may be found. In the case mentioned

$$d\theta = A \times 6 \times 10^{-8} \text{ radians,}$$

where $(d\theta)$ is the angular separation between the sodium lines. The angular separation between any desired pair of lines may be found in a similar

manner when the value $\left(\frac{d\theta}{d\lambda}\right)$ has been determined for the medium and the angle of the prism.

Resolving Power

The Theoretical Resolving Power of a spectroscope is defined as the ratio between the mean wavelength of a

pair of lines which can be just separated by the instrument and the difference of wavelength between the components,

$$R = \frac{\lambda}{d\lambda}$$

In an instrument which will just resolve the sodium lines the above equation would be

$$R = \frac{5893}{5896 - 5890} = 982$$

It can be proved mathematically that

$$r \left(\frac{\delta n}{\delta\lambda}\right) = \left(\frac{\lambda}{d\lambda}\right)$$

This equation shows that the resolving power is dependent only on the dispersion and (t) , which designates the base of the prism, used. That is, if dispersion remains unchanged as in the case of any given prism, the resolving power is proportional to the base of the prism and is independent of focal lengths or magnification.

It is to be remembered that the value of (R) is here computed for an infinitely narrow slit and for an infinitely narrow line. Neither of these conditions can hold in practice, so that the actual resolving power is always less than the theoretical.

Spectral Purity

According to the computations of Shuster, the following relations hold with respect to slit width, purity (practical resolving power) and intensity. The normal slit width as computed by Shuster is defined as follows: It is that width for which the extreme difference of path from one edge of the slit to the nearest and farthest edges

of the collimating lens is $\left(\frac{\lambda}{8}\right)$. This

slit is given the arbitrary factor of 1.0. It may be reduced to millimeters by

multiplying by the factor $\frac{f\lambda}{D}$ where (f)

is the focal length in millimeters, (λ) is the wavelength and (D) is the effective diameter of the lens.

The normal slit width (slit factor = 1.0) gives a purity of spectrum which is 1.4 per cent less than the maximum

possible. If the slit factor becomes 2.0, nearly double the amount of light is obtained and the purity falls only 5.7 per cent below the maximum. A gain of three times the light will mean a loss of about 20 per cent of the purity. A total intensity of 3.67 times that with the normal slit is accompanied by a loss of half the resolving power. Beyond this, widening the slit decreases the purity without great gain in intensity. On the basis of these facts, the mathematics of which we will omit, we can establish quite easily the relative efficiencies of different instruments.

Spectrum Length

In closing this section, we want to take a moment to point out that there are two features regarding spectrographs that are often confused. We refer to plate length or spectrum length and dispersion. If we refer to the definition of dispersion, we will find that it is independent of the focal length, or what amounts to the same thing, the magnification of the instrument. This means that to any given instrument we can give any focal length that we choose without altering the dispersion or the resolving power of the system. In other words, we can magnify the image to any size we may desire without altering the dispersion which is purely a function of the prism constants. To alter dispersion we must change either index or angle and to alter resolving power we must change the base of the prism, at the same time utilizing its full aperture.

While true dispersion is purely an angular function, it is often convenient to use a term which will indicate the separation on the spectrum plate corresponding to a given difference in wavelength. This depends on both true dispersion and focal length. It is usually referred to as "linear dispersion", and is expressed as the number of Angstrom units corresponding to one millimeter line separation. A large linear dispersion is thus indicated by a small number and vice versa.



Bunsen Spectroscope

THERE are several features of the Bunsen Spectroscope as manufactured by Bausch & Lomb which in the aggregate make it a very effective teaching tool.

One of the outstanding characteristics of this Bunsen Spectroscope is that it is completely adjustable throughout. The prism is held by a strong spring clip and may be moved at will. The prism table can be adjusted precisely by three thumb screws, allowing the teacher to demonstrate the effect of tilting the prism.

The slit, the scale, (in 0.1 mm intervals) and the viewing telescope are all focusable. A knurled thumb screw convenient to the left hand and outside of the prism case controls the

locking device for the horizontal movement of the viewing telescope. The slit is actuated by a thumb screw on the right hand side of its tube. The cover of the prism case may be lifted off. It sets firmly in place, protecting the prism from dust.

The construction of the instrument is exceptionally sturdy to withstand the great amount of handling and rough usage it will receive in the hands of inexperienced students. The pillar base is a heavy iron casting and forms a very strong and steady support. The finish is reagent and rust-proof crackled lacquer, lustrous black and chromium.

The results obtainable with the Bausch & Lomb Bunsen Spectroscope well meets the teacher's requirements. The two sodium D lines are resolved with little difficulty. The more important Fraunhofer lines are distinctly visible to the inexperienced observer. The scale, 15 mm in length, is divided into tenths of millimeters, thus providing an accurate arbitrary reference.

Direct Vision Spectroscopes

DIRECT Vision Spectroscopes have many applications in industry and education. They are useful in preliminary qualitative work, with both emission and absorption spectra, where a wavelength scale is not required, work such as the recognition of characteristic bright lines of metals and gases, transmission of colored glasses and photographic safelights. The more prominent Fraunhofer lines are well shown.

The optical system consists of a three-piece Amici prism of $6^{\circ} 15'$ dispersion between the C and F lines and an achromatic collimating lens of 32 mm, E.F., focusable on the slit. The same system is used in both models. All apertures are covered to keep out dust and prevent corrosion. The entire visual range is shown.

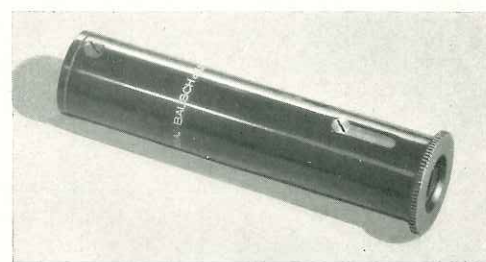
With Fixed Slit

The Fixed Slit Direct Vision Spectroscope is 16 mm in diameter and 80 mm long. The slit (0.1 mm wide) is ruled on a silvered glass disc, protected by a cover glass. This construction prevents "horizontal lines" and makes cleaning easy.

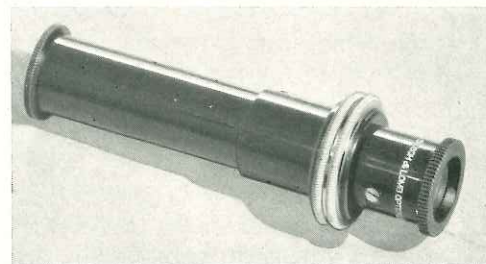
With Adjustable Slit

The Adjustable Slit Direct Vision Spectroscope is 16 mm in diameter and 95 mm long. The adjustable slit has jaws of stellite. The slit width is adjusted by turning a knurled ring. The construction is such that the jaws can not jam or stick. This model has a comparison prism introduced and removed from the light path by turning a second knurled ring. When in place, two spectra may be compared in the same field.

Both models are finished in instrument black to avoid bright reflections.



Above: No. 33-80-75. Below: No. 33-80-80

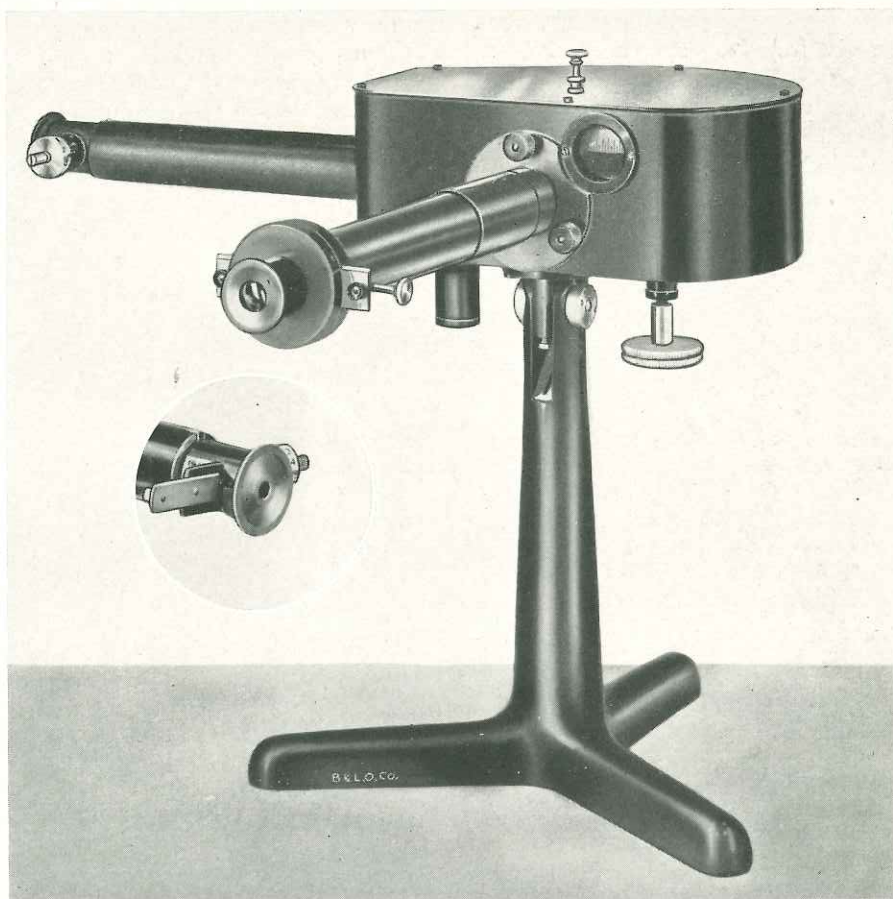


BAUSCH & LOMB

Catalog No.	Code Word	Specifications	
33-80-91	Kiodd	Bunsen Spectroscope, complete as described	
33-80-75	Kamil	Direct Vision Spectroscope, with fixed slit	
33-80-80	Kookm	Direct Vision Spectroscope, with adjustable slit and comparison prism	

*Laboratory
Wavelength
Spectrometer.*

*The insert shows
the Slit end
of the
Instrument.*



Laboratory Wavelength Spectrometer

Simplified Constant Deviation Prism Type

THIS Constant Deviation Prism Type Spectrometer with Wavelength Scale was designed to meet the needs of the routine laboratory worker. It is the same in principle as the Large Spectrometer, page 9, but is simpler in construction. The optical surfaces and moving parts are completely enclosed to protect them against dust and corrosion, thus insuring uniformly accurate and enduring service.

The dust-proof housing with removable cover plate contains the prism, its operating mechanism and

the graduated drum. The constant deviation prism is of the Pellin-Broca type and is made of a single piece of flint glass of high dispersion. The vertical surface upon which the light is incident is 22 mm in height and 45 mm in width. This prism is securely fixed to a prism table which is rotated by a cam attached to a vertical shaft. The shaft extends through the bottom of the housing and has an operating head at its lower end. At the other end of the shaft, above the cam, is the graduated drum—102 mm in diameter.

The graduations on the drum are in steps of one $m\mu$ from 400 to 600, in steps of two $m\mu$ from 600 to 650, and in steps of five $m\mu$ from 650 to 800. From 400 to 500 every fifth step is numbered and from 500 to 800 every tenth step. In order that the drum may be set to read for sodium light, a stop that extends through the cover holds the drum stationary while the cam and prism table are rotated, until the sodium line coincides with the eyepiece cross-hair.

A window (see illustration), with an index, is placed in such a manner

SPECTROMETRIC EQUIPMENT

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that the wavelength drum can be seen directly from the eyepiece position. The telescope and collimator are permanently aligned at right angles to each other. This construction is made possible by the fact that the constant deviation prism, however rotated, reflects the spectrum lines at a constant angle of 90 degrees.

This model of the spectrometer is equipped with the same adjustable slit that is used on the Large Spec-

trometer. Slit width is controlled by a micrometer screw and slit length by a V-slide operating close to the face of the slit jaws. In the slit mounting is a comparison prism by which auxiliary spectra may be introduced into half the field.

The telescope has a clear aperture of 20 mm and an E. F. of 160 mm. The objective is movable along the optical axis by means of a sliding collar surrounding the body tube. The eyepiece

holder is equipped with cross hairs and a shutter. The shutter provides for the suppression of parts of the spectrum not under observation and, further, permits the apparatus to be converted into a monochromator by removing the eyepiece. The shutters are operated by push rods extending through the sides of the casing.

A combined magnifier and scale illuminator No. 33-82-45 may be applied to the wavelength scale window. The scale is illuminated by a small shaded electric lamp, the current for which is supplied from a transformer or a dry cell battery.

An inclination joint on the standard of this instrument permits the observer to tilt the viewing telescope to any convenient angle and permits adaptation to other instruments.

Dispersion and Resolving Power

Wavelength (λ)	Prism Index (μ)	Dis- persion $\frac{d\theta}{d\lambda}$	Normal Slit Width (in mm)	Resolving Power (in $\text{\AA}$) for Various Slit Widths					
				Nor- mal $\times 1$	Nor- mal $\times 2$	Nor- mal $\times 4$	Nor- mal $\times 6$	Nor- mal $\times 8$	Nor- mal $\times 12$
7685 (A')	1.7053	-1053	.0016	3.57	3.73	4.51	6.07	7.82	11.31
6563 (C)	1.7131	-1693	.0013	1.92	2.00	2.42	3.26	4.19	6.07
5893 (D)	1.7201	-2402	.0012	1.23	1.28	1.55	2.09	2.69	3.89
4861 (F)	1.7377	-4827	.0010	0.52	0.55	0.66	0.89	1.15	1.66
4341 (G')	1.7532	-7755	.0009	0.30	0.31	0.38	0.51	0.65	0.94
4047 (h)	1.7660	-10777	.0008	0.20	0.20	0.25	0.33	0.43	0.62
4000	1.7685	-11422	.0008	0.19	0.19	0.24	0.32	0.42	0.61
Relative Brightness for Various Slit Widths				1.000	1.902	3.148	3.618	3.679	3.789
Angular Dispersion (C to F):				2 degrees and 47 minutes					
Angular Dispersion (A' to 4000):				7 degrees and 18 minutes					

Catalog No.	Code Word	Specifications
33-82-05-01	Kanak	Laboratory Wave Length Spectrometer, complete, as described, including adjustable slit, eyepiece shutter with cross hairs, and eyepiece 20mm E.F.
33-82-45-01	Kanup	Scale Illuminator, including dry battery
33-82-45-02	Klorz	Scale Illuminator, including transformer for 115 volt, 60 cycle A.C.
Replacement Parts		
71-71-24	Hoimm	Bulb, flashlight type, 3.8 volt for Scale Illuminators
71-72-40	Hyexl	Transformer, 115 volt, 60 cycle, for Scale Illuminator
71-72-80	Hoikk	Dry Battery, 4.5 volts, for Scale Illuminator

Optical Data for Spectrometer

Focal Length of Collimator Objective ($\lambda = 5893$)	162.6 mm
Focal Length of Telescope Objective ($\lambda = 5893$)	162.6 mm
Diameter of Collimator and Telescope Lenses	20.0 mm
Angle between Collimator and Telescope	90°
Eyepiece Magnification	14 $\times$
Prism Index of Refraction (n_D)	1.7201
Base of Equivalent Sixty Degree Prism	39.2 mm
Range of Spectrometer	4000 to 8000 Angstroms
Linear Length of Wavelength Scale	249 mm

Large Spectrometer

Constant Deviation Type with Wave Length Scale

THIS instrument is so designed that the optical and mechanical parts are completely enclosed.

The Constant Deviation Prism is of the Pellin-Broca type. The vertical surface upon which the light is incident is 30 mm in height by 45 mm in width. It is made of a single piece of flint glass of high dispersion and is firmly mounted by means of cleats on a rotating table within a dust-proof metal housing. This housing is provided with a cover that can be removed only by loosening several screws. The contact surface between the cover and the housing is protected

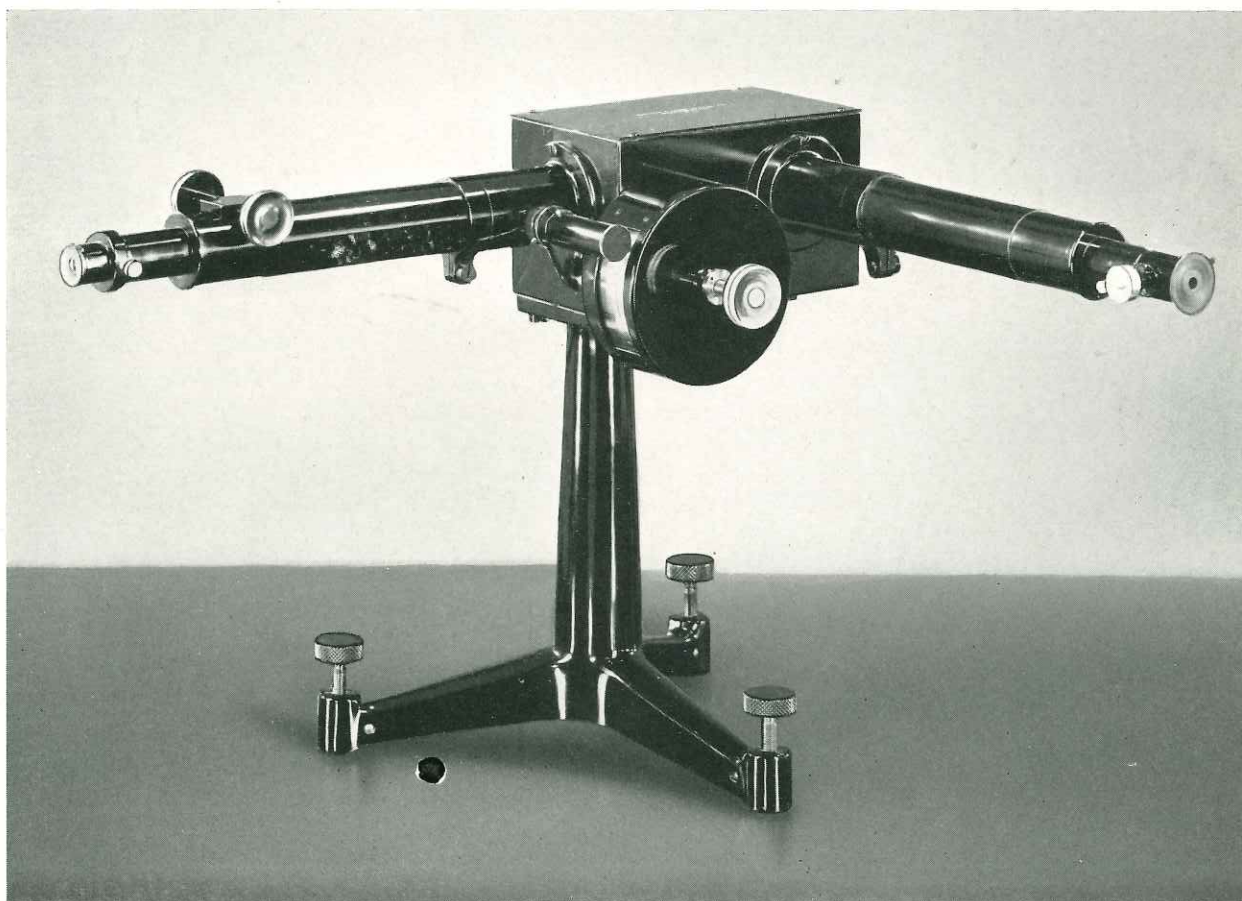
by a gasket to prevent the entrance of dust and fumes. When the prism is properly adjusted after the instrument is set up, this housing will need to be opened only at long intervals for inspection purposes. (See illustration page 10.)

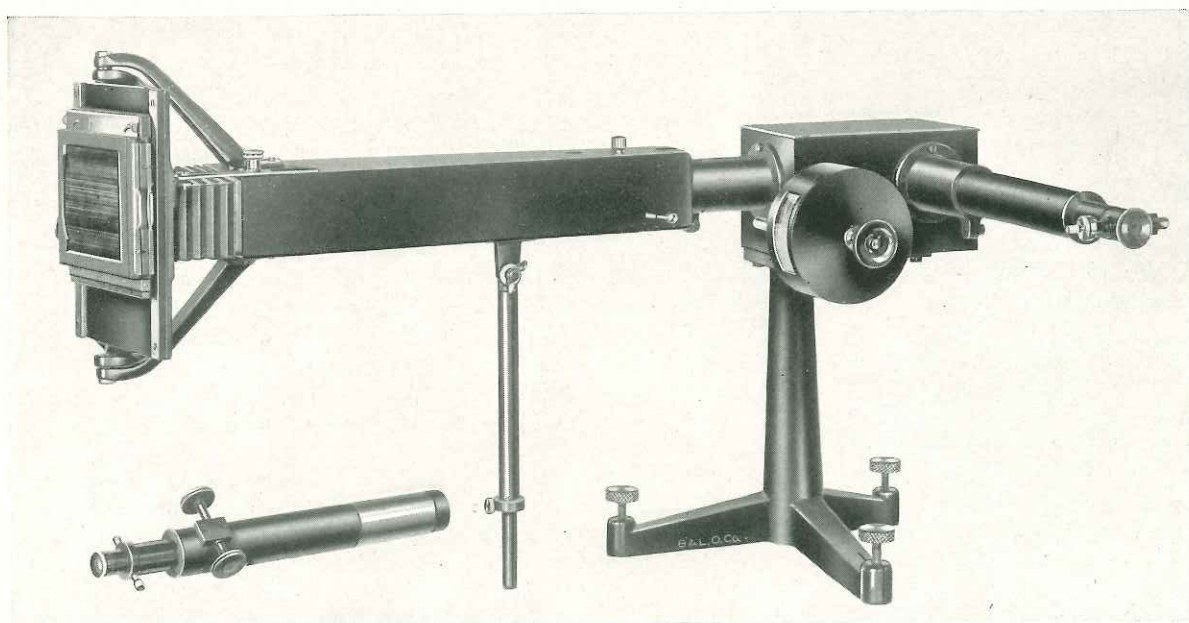
The rotation of the prism table to bring desired portions of the spectrum upon the central part of the field is accomplished by means of a micrometer screw which acts against a lug on the prism table and is operated by a knurled head outside the drum chamber. A strong spring keeps the lug always in contact with the point

of the screw and prevents backlash. The degree of rotation is measured on a drum on which the wave length scale is engraved. This drum is $3\frac{7}{8}$ inches in diameter and is graduated from 4000 to 8000 Angstroms. The numbering is in terms of $m\mu$.

The engraved scale is $26\frac{13}{16}$ inches long in units of $1\ m\mu$ with every fifth line numbered from 400 to 500 and every tenth line for the rest of the scale. It is in a spiral form, extending about $2\frac{1}{4}$ turns around the drum. Both drum and screws are encased for complete protection. Scale is read through a glass window.

Large Spectrometer shown with Scale Illuminator





Large Spectrometer with Camera

Illumination for the scale may be provided by means of a detachable lamp operating either from a transformer or dry battery. The focusing of the telescope is accomplished by means of a rack and pinion which moves the objective along the optical axis. This construction prevents lateral shifting of the image in focusing and makes possible a fixed position for the eyepiece. The E. F. of

the objective is 285 mm. The free aperture is 31 mm.

The eyepiece holder for the telescope has two cross-hairs at 60° to each other, mounted on a diaphragm plate which is adjustable laterally by a screw. The cross-hairs furnish a means of accurate setting on any spectral line.

The three observing eyepieces are aplanatic triplet systems which are of high quality. The focal lengths are $\frac{1}{2}$, $\frac{3}{4}$, and 1 inch.

Light from the source to be examined enters the collimator through an adjustable slit, the width of which is controlled by means of a micrometer screw with a head reading to 0.1 millimeter, its length being controlled by a movable blade with a notch in the end. The edges of the slit are sharp and clean. The jaws are of stellite, a non-corroding alloy which is extremely hard and well adapted to the purpose. A knurled ring provides for the introduction of the comparison prism over the slit so that two spectra may be examined in the same field. The instrument is finished in alcohol-proof black and a substantial wooden shipping case is provided for protection.

When fitted with the Shutter Eyepiece Holder, described on page 14,

the Large Spectrometer can be used as a monochromator.

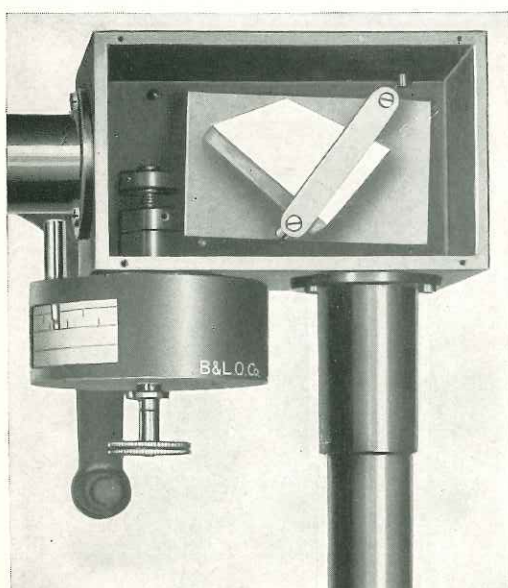
Optical Data for Spectrometer

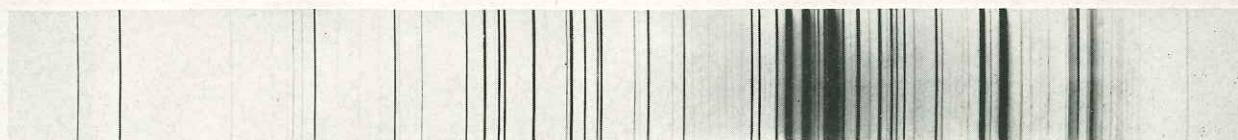
Focal Length of Collimator Objective ($\lambda = 5893$)	284.4 mm
Focal Length of Telescope Objective ($\lambda = 5893$)	284.4 mm
Diameter of Collimator and Telescope Lenses	31.0 mm
Angle between Collimator and Telescope	90°
Eyepiece Magnifications (3 supplied)	10X, 14X, 20X
Prism Index of Refraction (n_D)	1.7201
Base of Equivalent Sixty Degree Prism	35.5 mm
Range of Spectrometer	4000 to 8000 Angstroms
Linear Length of Wavelength Scale	648 mm

Spectrographic Camera

An all metal spectrographic camera has been designed for use with the Large Spectrometer. The construction has several features which will strongly recommend it, among which are especially noteworthy: (1) The body of the instru-

Prism Assembly





Copper Spectrum—Visual Portion (enlarged three times). Photographed with Large Spectrometer, Catalog No. 33-82-09-01.

ment is a hollow aluminum casting to which the auxiliary metal parts are firmly attached. The elimination of all wood from the construction reduces to a minimum the possibility of warping and shifting and insures the permanence of adjustments after they are made. (2) The plate holder frame is so arranged that the plate rotates about the center of the emulsion surface. This greatly reduces the time necessary to put the camera in focus over the entire length of the spectrum by photographic means.

As illustrated on page 10, the Camera replaces the telescope of the spectrometer. The lens, which has a focal length of 533 mm, is fitted into a sliding mount which permits easy focusing. A millimeter scale and a reference line serve to determine its position.

The plate holder frame, which is connected to the main body of the camera by a bellows, can rotate about its own center. It is provided with a means for clamping firmly at any desired angle. A scale is attached so that settings may be repeated. A rack and pinion adjustment allows the plate holder to be moved vertically in the focal plane so that successive exposures may be made on the same plate. The position of the plate is also determined by a scale and index.

A simple flap shutter is provided for making time exposures. The shutter is operated by a rod which extends through the casting.

The entire camera is finished in a dull black similar to that used on the Spectrometer. All scales are chromium plated.

Optical Data for Camera

Focal Length of Camera	
Lens ($\lambda = 5893$)	533.0 mm
Diameter of Camera	
Lens	31.0 mm

Photographic Range

	3750 to 10000 Angstroms
Spectrum Length from	
3750 to 5800 Å	65.0 mm
Plate Size	3 1/4 x 4 1/4 inches

Dispersion and Resolving Powers

Wavelength (λ)	Prism Index (μ)	Dis- persion $\frac{d\theta}{d\lambda}$	Normal Slit Width (in mm)	Resolving Power (in Å) for Various Slit Widths					
				Nor- mal ×1	Nor- mal ×2	Nor- mal ×4	Nor- mal ×6	Nor- mal ×8	Nor- mal ×12
7685 (A')	1.7053	-1053	.0030	3.94	4.12	4.98	6.71	8.63	12.51
6563 (C)	1.7131	-1693	.0026	2.12	2.22	2.68	3.61	4.65	6.73
5893 (D)	1.7201	-2402	.0023	1.36	1.42	1.72	2.32	2.98	4.32
4861 (F)	1.7377	-4827	.0019	0.57	0.60	0.72	0.97	1.25	1.81
4341 (G')	1.7532	-7755	.0017	0.33	0.35	0.42	0.56	0.72	1.05
4047 (h)	1.7660	-10777	.0016	0.23	0.24	0.29	0.39	0.50	0.73
4000	1.7685	-11422	.0016	0.22	0.23	0.28	0.38	0.48	0.70
Relative Brightness for Various Slit Widths				1.000	1.902	3.148	3.618	3.679	3.789
Angular Dispersion (C to F):				2 degrees and 47 minutes					
Angular Dispersion (A' to 4000):				7 degrees and 18 minutes					

Catalog No.	Code Word	Specifications
33-82-09-01	Kajaf	Large Spectrometer, as described, including adjustable slit, cross line eyepiece holder, and three eyepieces of 1/2", 3/4" and 1" focal lengths
33-82-49-01	Kajeg	Scale Illuminator, including dry battery
33-82-49-02	Kopib	Scale Illuminator, including transformer for 115 volt, 60 cycle A.C.
33-82-35	Kajih	Shutter Eyepiece Holder, without eyepiece, as described. (If not furnished at time of purchasing spectrometer, telescope tube must be returned to factory for fitting)
33-82-29-01	Kakul	Spectrographic Camera, complete as described, including focusing objective, shutter, plate holder, and focusing screen
Replacement Parts		
33-82-14	Kakag	Aplanatic Eyepiece—1/2" focal length
33-82-15	Kakeh	Aplanatic Eyepiece—3/4" focal length
33-82-16	Kakij	Aplanatic Eyepiece—1" focal length
71-71-24	Hoimm	Bulb, flashlight type, blue glass, 3.8 volt, for Scale Illuminator
71-72-40	Hyexl	Transformer, 115 volt, 60 cycle, for Scale Illuminator
71-72-80	Hoikk	Dry Battery, 4.5 volts, for Scale Illuminator
42-15-21	Cezup	Plate Holder, Double, for Camera for 3 1/4" x 4 1/4" Plates

Equipment for Spectrophotometry

THERE are two classes of methods in common use for the determination and specification of color. The so-called colorimetric methods, either monochromatic or trichromatic, define this property in terms of some chosen stimulus which has been found to produce subjectively the same sensation. The spectrophotometric methods, on the other hand, analyze color by measurement of the actual radiant energy producing the sensation. Colorimetry measures sensation; spectrophotometry measures the actual stimulus.

It will be seen at once that the colorimetric methods, measuring, as they do, a psychological effect or sensation, must be subject to abnormalities of the observer's color vision. The spectrophotometric method, on the other hand, removes the factor of color difference and reduces the measurements to a simple comparison of the transmission or reflectance of any substance which, when obtained by the latter method, constitutes the fundamental

specification of the color of that substance. For ultimate standardization colorimetric methods rely on spectrophotometric methods, in that filter transmission and spectral distribution of sources must be determined by the fundamental method of radiant energy determination.

Among the direct applications for spectrophotometric methods may be mentioned the analysis of structure and purity of chemical compounds, the suitability of protective glasses, the transmission of photographic or photometric filters, etc. Recent developments show that the physical condition of the human body and the progress of disease may often be studied by means of a spectrophotometric analysis of the body fluids.

Most of the modern types of dyes show marked absorption characteristics which are dependent on the structure of the dye. The spectrophotometer, by analyzing the color,

enables the technologist to determine purity and percentage composition in his specimens.

Finally, it may be mentioned that the instruments find another field in psycho-physical optics in visibility and hue sensibility determinations.

A spectrophotometer consists essentially of three units:

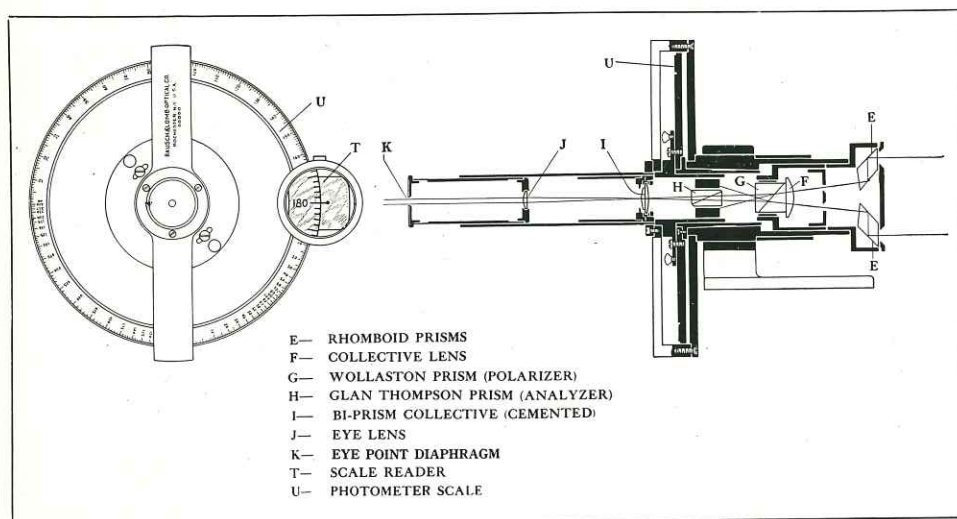
1. *A means of illumination for the sample.*
2. *A rapid means of varying and comparing light intensities—the Photometer described below.*
3. *A spectrometer which divides the transmitted beam into its constituent colored components—the Large Wave Length Spectrometer described on pages 9 to 11.*

The Polarization Photometer

It has long been recognized that polarization photometry, while subject to certain disadvantages, is one of the simplest and quickest methods for the comparison of light intensities. In a photometer of this type no other optical system offers so good a solution of the problems as that consisting of a Wollaston double image prism combined with a bi-prism and analyzing prism.

In general, the polarization photometer is one in which the two halves of the comparison field are polarized at right angles to each other. Variation of intensity between the halves is made by rotation of an analyzer prism, the movement of which is read on a divided circle.

Optical System of Photometer



Versatile in Application

The instrument is designed with two ends in view. (1) When used in conjunction with the standard light source, it is an excellent white light photometer and will serve for accurate measurement of light intensity. When used alone in connection with an extended uniform source, it offers means for the measurement of photographic densities and work of a like nature. (2) When used with the Bausch & Lomb Large Spectrometer and the Universal Stand, it provides a complete Spectrophotometric outfit of a high order of accuracy. It will then give over the visual range readings from which spectral transmission and density curves may be directly plotted.

Improved Martens Type

The photometer, as shown, is essentially of Martens type, but, due to the rearrangement of elements, some disadvantages of this type have been overcome. It will be seen from the description that a single rotation of the analyzer will result in the complete extinction of each field twice or in four so-called extinction points which are 90° apart. Between each pair of extinction points will lie the zero points—these are the positions of the analyzer in which the two halves of the field will be matched. In previous designs there has always existed a zero point variation, caused by the action of an inclined refracting surface lying between the polarizer and the analyzer. In the original Martens type the offending unit is the bi-prism. In that design two beams, polarized perpendicularly to each other, are incident on the opposite inclined faces of the bi-prism. Due to the difference in effect of the inclined surfaces on the polarized beam, the amount of light transmitted by the two halves of the bi-prism is not the same and consequently the zero point of the instrument is not exactly 45° . This precludes the use of any type of direct reading which would be correct in the direct and reversed position of the photometer.

Designed for Efficiency

The new design, however, places the analyzer so that there are no interfering elements between it and the polarizer. The light coming to the bi-prism in both beams is linearly polarized in the same plane and consequently the action of the bi-prism on each beam is the same. Hence, a direct reading scale in densities, transmissions or absorptions may be used on the rotating analyzer circle. The circle on this instrument is graduated to read either directly or indirectly. One quadrant is graduated in densities, a second in transmission (in percent) and the third and fourth in degrees. The diameter of the circle is 6 inches, giving ample space for distinct graduation. It is of chromium, the lines being filled in black.

Greater Accuracy in Reading

In order to avoid erroneous readings due to polarization in the sample, two methods have been in common use: (1) To read the sample over both apertures of the photometer and take an average of the two readings. (2) To reverse the photometer and take the average of the two readings. These methods are equivalent, if the illumination on both apertures of the photometer is exactly similar in intensity and condition. The first method is correct under any set of conditions with respect to inequality of illumination. In the latest model of the photometer the instrument itself is fixed and a rotating device is provided on the spectrophotometric stand by which solid specimens may be shifted from one beam to the other.

Wide Field Separation

In the case of liquids the tubes themselves must be shifted from one saddle to the other in order to take readings in both positions. The wide field separation, which proves so useful in certain types of work where the use of large samples is

necessary, has been secured by the use of rhomboid prisms in which the light paths are altered by two total reflections. Since total reflection gives no polarization, this feature insures that there will be no disturbing effect due to reflection or refraction before the light beams reach the Wollaston prism, where they are polarized perpendicularly to each other.

Photometric Conversion Formula

When reading by the indirect method, i.e., in circular degrees, the following formulae are used to convert to other values:

$$T = \cot^2 (\text{larger angle}) \tan^2 (\text{smaller angle})$$

The larger angle may be either the zero angle or the angle at the match point. This is determined by the region in which the match point falls. Assuming the zero point to be 46° and that a match point is obtained at 60° , the formula would then read:

$$T = \cot^2 60^\circ \times \tan^2 46^\circ, T = 0.3574 \text{ or } 35.74\%$$

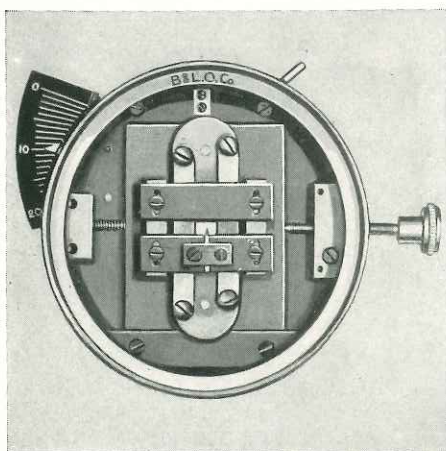
Assuming again the same zero point (46°) and the sample placed over the other aperture, the reading would then be $31^\circ 46'$.

$$T = \cot^2 46^\circ \times \tan^2 31^\circ 46', T = 0.3574 \text{ or } 35.74\%$$

In the problem chosen above, the operation is equivalent to the reversal of the sample. It will be seen that the angular rotations from 46° are not the same. This condition will always occur when the zero point is not exactly 46° . If the sample is read on both sides of the zero point, i. e., if sample is reversed and a second reading taken, the above formulae reduce to the following:

$$T = \cot (\text{larger angle}) \times \tan (\text{smaller angle})$$

In this formula the larger angle would be 60° in the above problem and the smaller angle would be $31^\circ 46'$.



Shutter Eyepiece Holder

$$T = \cot 60^\circ \times \tan 31^\circ 46', T = 0.3574 \text{ or } 35.74\%$$

Having transformed the angular readings into transmission, other values are easily found as indicated below:

$$A (\text{Absorption}) = 1 - T$$

$$D (\text{Density}) = \log \frac{I}{T}$$

The Shutter Eyepiece

The B & L Shutter Eyepiece allows a rectangular section, vertical to the dividing line and of any desired width, to be selected and compared. The length of the field and the intensity of illumination are respectively controlled at the entrance slit of the spectrometer by the V slide and the micrometer screw. The two halves of the rectangular field thus formed are brought to equality of brightness by means of the analyzer of the photometer, which is controlled from the observer's position at the eyepoint of the spectrometer. Thus successive portions of the spectrum may be examined and compared and from the data a complete transmission or density curve plotted.

Within a flat cylindrical case are mounted two adjustable shutters, and a reference pointer. The shutter blades lie in the focal plane of the telescope and are manipulated simultaneously by means of a lever extending upward at the back of the

case. A sector with an arbitrary scale indicates the opening between the blades. In the Spectrophotometric set-up these blades serve to limit the portion of the spectrum to be observed. They are also useful for observation and measurement of faint lines between bright lines when the spectrometer is being used on line spectra. The reference pointer, whose lateral motion is controlled by a screw, takes the place of cross hairs in the ordinary eyepiece. It may be adjusted as to height, so that it can be observed with any width of spectrum.

Modified Ocular System

Some observers accustomed to the circular type of photometric field find it difficult to use the rectangular field described. For those who desire it, another system is provided which gives the conventional circular field with a horizontal dividing line. The auxiliary lens, used at the photometer eyepoint for the rectangular field, is replaced by a long focus auxiliary lens which images the photometer field in the collimator objective of the spectrometer. The eye lens of the shutter eyepiece is removed and used as the eyepiece of a small observing telescope which goes into the original position of the spectrometer eyepiece and focuses upon the collimator objective.

This system gives a circular homochromatic field, the purity of which is controlled by the width of the exit slit in the focal plane of the telescope objective. In general practice, however, it is recognized that the first type of field described, i. e., the juxtaposed spectra type, possesses certain advantages, viz: (1) stray light is comparatively unimportant; (2) any rapid changes in intensity of either spectrum can at once be seen. On the other hand, the homochromatic field gives complete uniformity of illumination, where passing through sharply defined absorption bands, while the juxtaposed spectra type of field will show differences of illumination at different points in the dividing line. It has been our experience with this

instrument that there is little choice of field type as far as accuracy of reading is concerned.

The Auxiliary Lens

For spectrophotometric determinations the eyepiece diaphragm of the photometer is removed and an auxiliary lens of short focal length substituted. This lens images the photometric field upon the slit of the spectrometer. The spectrometer re-images the field and its dividing line in the focal plane of the telescope objectives giving two adjacent spectra.

Mechanical Features

A cast metal base is provided to furnish a solid and fixed support for the combined instruments. The stand with the ventilating motor, if it is being used, is fixed firmly to the base. Clamps are provided for the motor and the stand. The spectrometer is placed upon the base with the leveling screws in the cone shaped depressions provided. These depressions are in flat members which are movable to secure final adjustments of the spectrometer with reference to the photometer. The moving members are freed by loosening the screws holding the cover plates. When the spectrometer is finally adjusted, the holding screws may be tightened, and the members having the depression in them will be held in fixed position.

There is provided, as an accessory, a rod and contact wheel, by which the photometer circle may be operated from the left side of the spectrometer. A sliding bearing for the rod allows the contact wheel to be disengaged at will. The scale illumination of the spectrometer and the photometer is secured by means of a single lamp on the spectrometer. A lens and a prism in the end of the lamp tube throw direct light upon the photometer scale. Indirect light from the white inner wall of the tube illuminates the wave length scale. The lamp of the illuminator is operated from a transformer connected for use on A. C. or from a dry cell battery.

The Universal Spectrophotometric Equipment

Four Specialized Outfits for Work in Research and Industrial Laboratories

THE basic parts of the Universal Spectrophotometric Equipment are the Spectrometer, Photometer, Universal Stand and Base Casting. By adding appropriate parts, suitable equipments are made available for various types of spectrophotometric work.

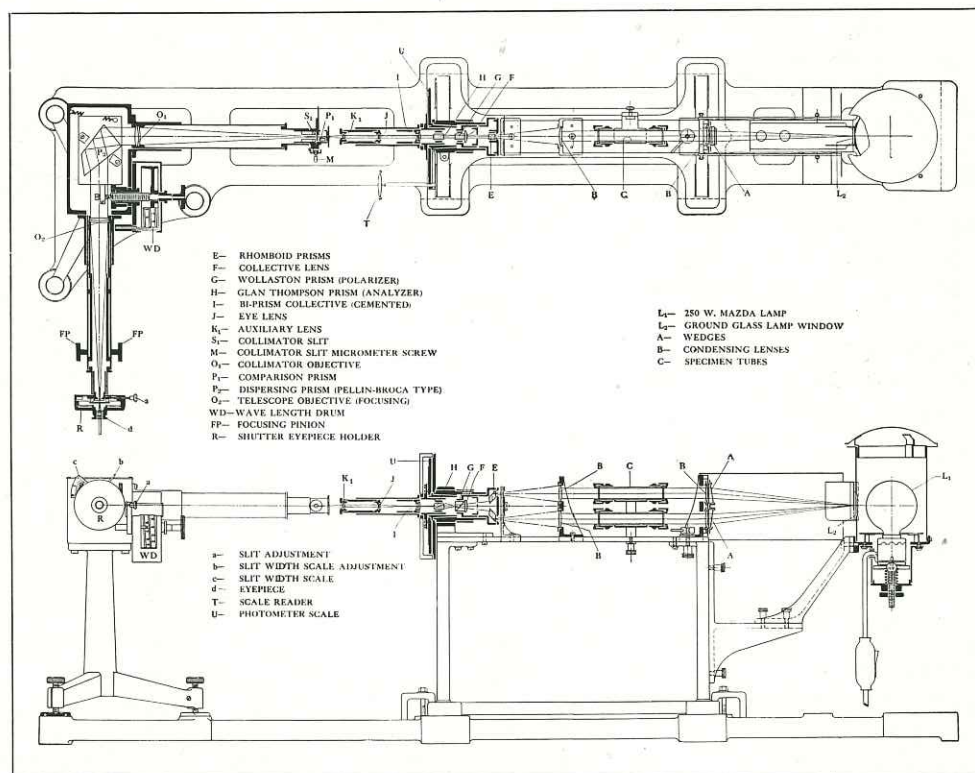
To make clear the universal nature of the stand we offer four arrangements in the following pages. The chart on page 17 shows at a glance the parts common to all equipments and the interchangeable parts used to convert one equipment to another. In any of them the parallel beam is

ultimately focused on the photometer aperture, giving an intense illumination in the field of the photometer.

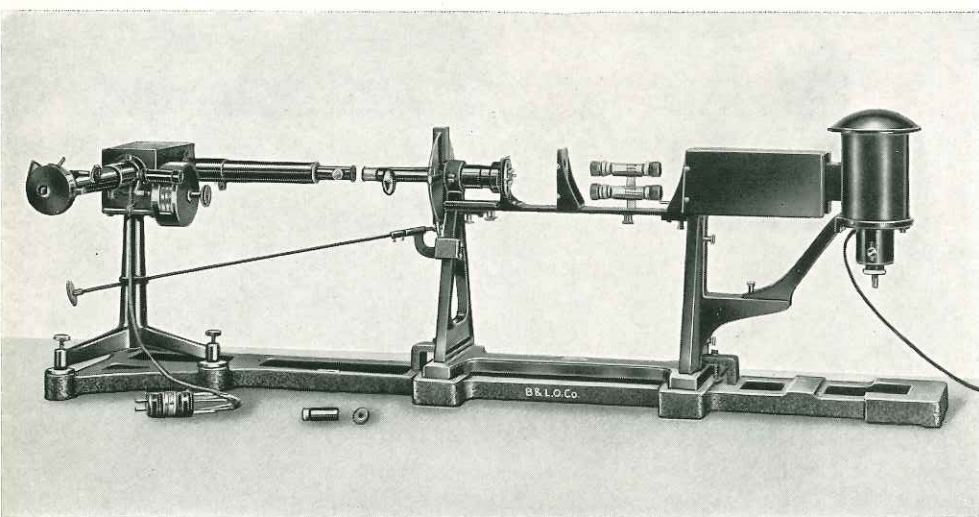
If the standard arrangements suggested do not meet a given requirement, substitute parts may be selected from the itemized parts list on page 19.

Equipment No. 1

For Transmission Measurements Through Fixed Thickness



*Drawing of Equipment No. 1
showing optical parts and path
of light.*



Spectrophotometer showing specimen tubes in place.

Catalog No.	Code Word	Specifications
33-88-40-02	Kopez	Spectrophotometric Outfit, complete for transmission measurements on transparent solids and liquids at fixed thickness, for 115 volt D.C. or A.C. with scale illuminator and transformer for 115 volt, 60 cycle A.C.
33-88-40-04 33-82-99	Kopoc Kosab	Same, but with scale illuminator, with dry battery Special Shipping Case for stand and illuminating unit on above outfits—deposit, refunded on return of case

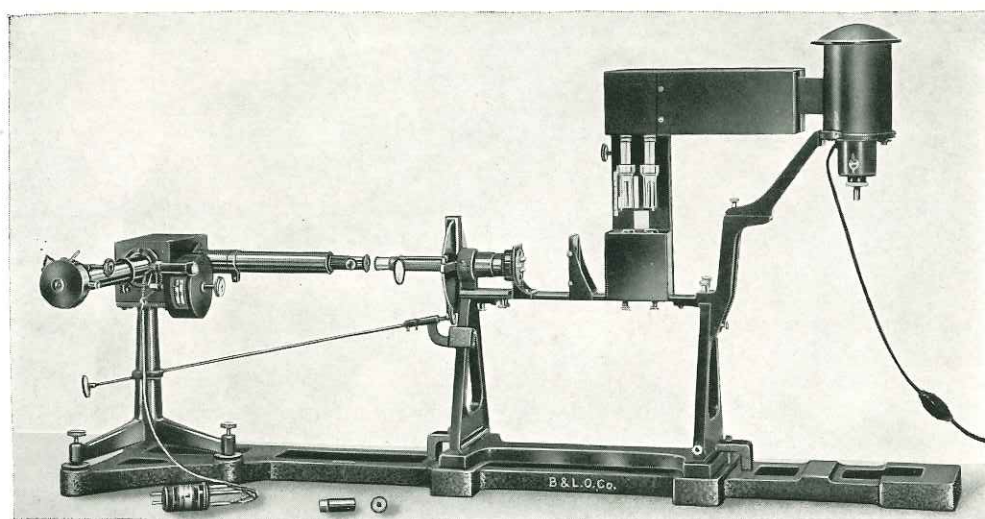
This is the simplest arrangement and serves for transmission measurements on transparent solids and upon liquids held in specimen tubes of constant length. The stand carries a ventilated lamphouse in which is mounted a 250 watt Mazda lamp. The light from this source is passed through a double ground glass window. The photometer is mounted on the opposite end of the stand and between the two are mounted specimen tube holders and a lens and prism system.

The specimen tubes are held in saddles, adjustable vertically to bring them into correct alignment in the light paths. The function of the lens system is to furnish, from the single source, two parallel beams of light into which the specimen tubes may be placed and then to focus the beams upon the aperture of the photometer. A 25 watt Mazda lamp is provided to be used where low intensities are desired in white light photometry.

(See chart on page 17 and parts list on page 19 for detailed list of parts included.)

Equipment No. 2

For Transmission Measurements at Both Fixed Thickness
and Through Variable Thicknesses



Spectrophotometer for Transmission measurements through fixed and variable thicknesses.

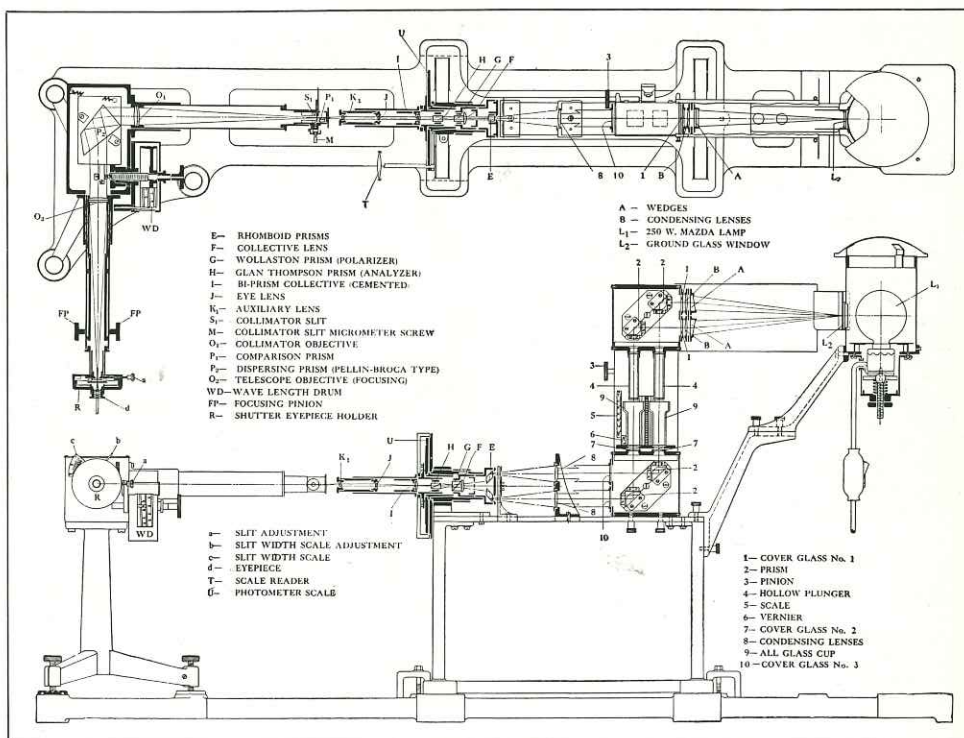
This equipment enables the operator to make transmission measurements on transparent liquids and solids and to have the liquid columns adjustable to any desired depth up to 65 mm. It is identical with equipment Number 1 except for the addition of the vertical specimen holder attachment which is useful in obtaining transmission measurements of samples at different thicknesses, as required in recent developments in the technology of dyes and biological stains.

The illustration on page 16 shows the equipment arranged for making transmission measurements through variable thicknesses. The tubes of fixed length and necessary lenses in illustration of Equipment No. 1 shown at top of page 16 are also included. A vertical casting is attached to the bed of the stand.

Upon this casting are mounted right angle prisms to alter the direction of the light beams so that they will pass vertically downward through cups and plungers of the colorimeter type. The plungers are of hollow design and are fixed in position. The cups are of the flare top type and are movable together by rack and pinion. The movement is read on a scale and vernier, reading to tenths of a millimeter. Suitable lens systems serve to give parallel light through the cups and plungers.

When ordering the specimen holder separately, the photometer and stand must be sent to the factory for attachment of the holder and proper alignment of parts.

This table shows equipment required for Transmission and Reflection Outfits. See page 19.



Drawing of Equipment No. 2

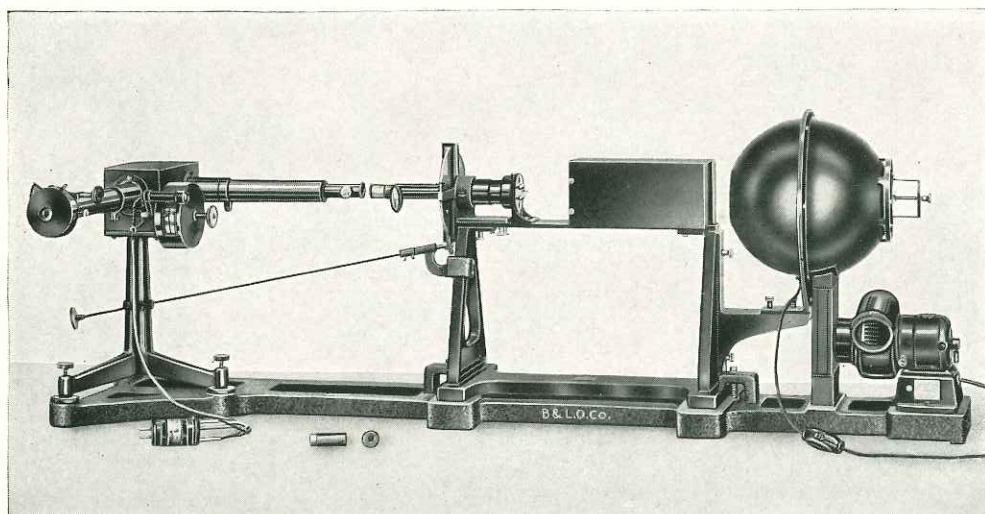
Catalog No.	Code Word	Specifications
33-88-40-12	Kopud	Spectrophotometric Outfit, complete for transmission measurements only on transparent solids and liquids at fixed thickness and on liquids at varying column heights, for 115 volt, D.C., or A.C., with scale illuminator with transformer for 115 volt, 60 cycle A.C.
33-88-40-14 33-82-99	Koraz Kosab	Same, but with scale illuminator with dry battery Special Shipping Case for stand and illuminating unit on above outfits—deposit, refunded on return of case.

Chart of Parts Used in the Equipments

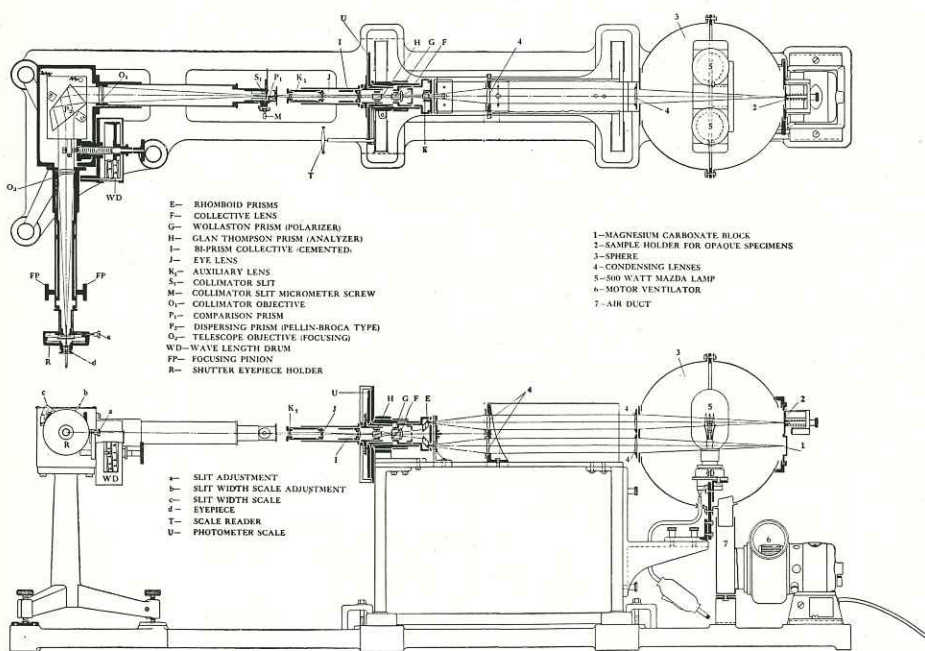
Item	Catalog No.	No. 1 Transmission only	No. 2 Transmission only—fixed and variable thicknesses	No. 3 Reflection only	No. 4 Transmission and Reflection
Spectrometer	33-82-09-01	X	X	X	X
Shutter Eyepiece	33-82-35	X	X	X	X
Photometer	33-88-40	X	X	X	X
Auxiliary Lens	33-82-72	X	X	X	X
Universal Stand	33-82-81	X	X	X	X
Base	33-82-82	X	X	X	X
Operating Device	33-82-69	X	X	X	X
Scale Illuminator	33-82-48-01	X	X	X	X
	or				
	33-82-48-02	X	X	X	X
Special Shipping Case (Note: The above parts required on all outfits.)	33-82-99	X	X	X	X
Parts for Transmission Measurement (see parts list)	33-82-74-01	X	X		X
Motor Ventilated Sphere	33-82-73-01			X	X
Specimen Holder for varying thicknesses of specimen	33-82-86-01		X		

Equipment No. 3

For Reflection Measurements



*Spectrophotometer for
Measuring Opaque Objects.*



Drawing of Equipment No. 3

For measuring reflectance curves of opaque samples, an 11 inch fan ventilated sphere is provided on Equipment No. 3. The sphere is made of copper with the interior surface white, and contains two 500 watt Mazda lamps. It is provided with a rotary specimen holder so made that the sample under observation may be brought before either aperture of the photometer. The comparison source is a standard white of a high coefficient of reflection. The sphere may also be used for transmission measurement, in which case the rotary holder brings the standard white before both apertures of the photometer. A double lens system gives parallel beams through the specimen tubes or samples which are held, as in the first arrangement, in front of the exit aperture of the sphere. The ventilating system is arranged so that cool air from the room is drawn over the sample, when reflection measurements are being made, to protect it, as far as possible, against deterioration of color due to heat.

(See chart on page 17 and parts list on page 19 for detailed list of parts included.)

Catalog No.	Code Word	Specifications
33-88-40-22	Koreb	Spectrophotometric Outfit, complete, for reflection measurements only on opaque specimens, for 115 volt D.C., or A.C., with scale illuminator with transformer for 115 volt, 60 cycle A.C.
33-88-40-24 33-82-99	Koric Kosab	Same, but with scale illuminator with dry battery Special Shipping Case for stand and illuminating unit on above outfits—deposit, refunded on return of case.

Equipment No. 4

For Transmission Measurements Through Fixed Thickness, and Reflection Measurements

This equipment offers the combined facilities of Equipments 1 and 3. Both the ordinary lamp house and the ventilated sphere are included. With the correct assembly, according to the chart on page 17, transmission measurements can be made on transparent solids and liquids (in tubes of fixed length) and reflection measurements made of opaque specimens.

(See chart on page 17 and parts list below for detailed list of parts included.)

Catalog No.	Code Word	Specifications
33-88-40-32	Korod	Spectrophotometric Outfit, complete, for transmission measurements on transparent solids and liquids, at fixed thickness, and reflection measurements, for 115 volt, D.C. or A.C., with scale illuminator with transformer for 115 volt, 60 cycle A.C.
33-88-40-34 33-82-99	Koruf Kosab	Same, but with scale illuminator with dry battery Special Shipping Case for stand and illuminating unit on above outfits—deposit, refunded on return of case

Universal Spectrophotometric Outfits Parts List

The following detailed list of parts is offered for purposes of replacement or for the addition of new parts to existing outfits. See chart on page 17 for listing of parts necessary for various types of work.

Catalog No.	Code Word	Specifications
33-82-09-01 33-82-35	Kajaf Kajih	Large Spectrometer , as described on page 11. Shutter Eyepiece Holder ,** without eyepiece, for Large Spectrometer, as described on page 14.
33-82-71 33-88-40	Kaors Kaovw	Modified Ocular System ,** as described on page 14. Photometer , as described on page 12.
33-82-48-01 33-82-48-02	Kaopr Kotif	Scale Illuminator , including dry battery, as described on page 9. Scale Illuminator , including transformer for 115-volt, 60-cycle A.C., as described on page 9.
33-82-72 33-82-69	Kalik Kaost	Auxiliary Lens , as described on page 14. Operating Device , as described on page 14.
33-82-82 33-82-81	Kaomn Kosid	Base for complete spectrophotometric outfit, as described on page 14. Universal stand only , for photometer, illuminating units and specimen tubes; including light shield, adjustable specimen tube saddles, rotating specimen holder and front set collimating lenses.
33-82-74-01	Kotog	Note: Add one or more of the following units as required: For fixed thickness transmission measurements with horizontal absorption tubes: Lamp House and supporting bracket, with 33-33-51 bulb, 250 watt, 115 volt A.C. or D.C., and 33-33-41 bulb, 25 watt, 115 volt A.C. or D.C., interchangeable, rear set collimating lenses in supports, and pair of specimen tubes. (Must have stand and photometer at factory for fitting.)
33-82-86-01	Kaojk	For variable thickness transmission measurements with vertical colorimeter type absorption cups: Specimen Holder complete with one pair cups and plungers, and extension bracket for illuminant, described on page 17. (Must have photometer and stand at factory for fitting.)
33-82-73-01	Kaotv	For reflection measurement: Motor-ventilated sphere, with two 41-41-08 Mazda bulbs, 500 watt, 115 volt A.C. or D.C., as described on page 18.
33-82-99	Kosab	Special Shipping Case for holding Universal stand, photometer and illuminating unit assembled—deposit, refunded on return of case.
		Replacement Parts
33-82-88-02	Kalum	Specimen Tubes ,* 100 mm, for use on stand 33-82-81.
33-62-31	Kaevt	Cover Glasses , 23 mm diameter, for 33-82-88-02 Tubes.
33-82-61	Kaolm	Cups ,* 65 mm, all glass, for specimen holder 33-82-86-01.
33-82-62	Kopay	Plungers ,* hollow, for specimen holder 33-82-86-01.
33-33-51	Konuc	Bulb , Mazda, Stereo type, 250 watt, 115 volt, for Lamp House on parts set, 33-82-74-01.
33-33-41	Klubl	Bulb , Mazda 25 watt, 115 volt, for use on parts set 33-82-74-01.
71-71-24	Hoimm	Bulb , flashlight type, 3.8 volt, for scale illuminator.
41-41-08	Doekd	Bulb , Mazda, projection type, 500 watt, 115 volt, for sphere 33-82-73-01.
71-72-40	Hyexl	Transformer , 115 volt, 60 cycle A.C., for scale illuminator.
71-72-80	Hoikk	Dry Battery , 4.5 volt, for scale illuminator.

*Purchase in matched pairs or to match one in service.

**If not furnished at time of purchasing spectrometer, telescope tube must be returned to factory for fitting.

Quartz Ultra-Violet Monochromator

For Obtaining an Intense Monochromatic Light

A NEED is often found by the physicist or scientific worker for a source of ultra-violet monochromatic light. Instruments hitherto available for this purpose have been notably deficient in the intensity of

illumination delivered, owing to adherence to conventional optical construction. In this instrument Bausch & Lomb has achieved a real innovation in the field of quartz optical systems, and its performance with the usual sources of illumination leaves little to be desired.

In the design of the instrument the effort has been directed toward the attainment of the following characteristics:

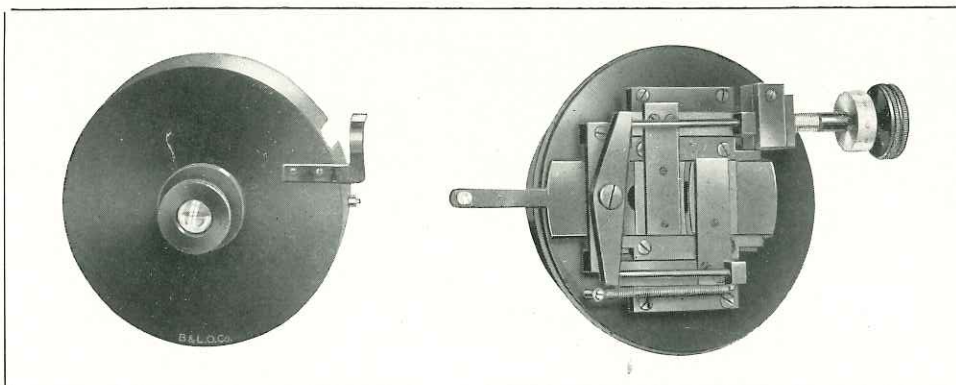
1. Constancy of deviation, permitting the use of a wavelength scale.
2. The use of small pieces of quartz for conservation of light and economy of material.
3. High light gathering power.
4. Ruggedness, durability and convenience in use.
5. A minimum of internal reflections and stray light.

The prism system is of the Thollon type and consists of two quartz prisms, rotating simultaneously in opposite directions under action of the wavelength screw, while the telescope and collimator are fixed, the angle between them being $128^{\circ} 52'$.

Of the two prism elements, one is made of right and the other of left quartz as in the Cornu prism. When the prisms are normal to the telescope and collimator, the system is arranged to transmit light of wavelength 2,000 Angstrom units so that, at that point, reflection losses will be at a minimum.

Bausch & Lomb Quartz Ultra-Violet Monochromator





*Left: Eyepiece
and eyepiece cap.
Right: Detail of Slit,
eyepiece cap removed.*

The prisms are arranged to rotate about vertical axes, passing through the centers of the hypotenuse faces. They rotate equal amounts, one clockwise and the other counter-clockwise. The quartz optic axes are so located that when the prisms are at the center of this rotation, the light within the prisms is passing parallel to the axes. The result is that there is zero doubling at the center of the spectrum and equal but opposite doubling at the extremes, the amount at the extreme being $0^{\circ}1'10''$ which has been found to be of no consequence.

The objectives are of high relative aperture and are made of a single piece of quartz with aspheric surfaces. This construction leads to high light gathering power. Correction of objectives with spherical curves may be carried satisfactorily to an aperture ratio of $f:4.5$ by using two separated elements, but this involves four reflecting surfaces in each objective with attendant reflection-image difficulties and high reflection losses, not to mention the additional quartz required. By using aspheric surfaces it was found possible to make objectives of a single piece of quartz each, working at $f:4.0$ for 2,000 Angstrom units and at $f:4.9$ for 8,000 Angstrom units with excellent definition. The objectives are of 150 mm focus for sodium light and of 31 mm free aperture.

Provision is made for removal of the prisms for cleaning and re-

placement without the need for a long and tedious readjustment.

Unsatisfactory cone type table bearings have been eliminated.

The B & L sturdy wavelength screw is not likely to wear easily and has provision for taking up any wear.

General Specifications

I. GENERAL

The instrument is of the constant deviation type with wavelength scale. It is supported by a column and tripod with leveling screws. The finish is all black, crystal and enamel. All operating drums and buttons are on one side and all scales are read at the top from the eyepiece end of the instrument. The prism, prism bearings, prism actuating mechanism, wavelength screw, wavelength drum and all optical parts are completely en-

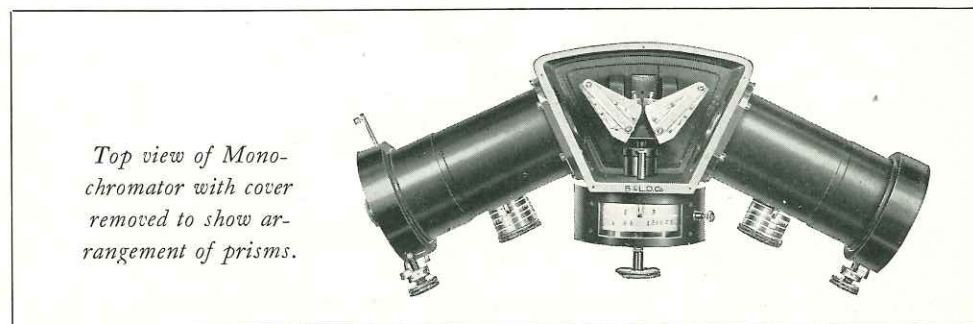
closed and therefore protected against dust and injury.

II. THE PRISM SYSTEM

Consists of two symmetrically rotating 30° prisms of quartz, so arranged as to reduce doubling of images, due to double refraction, to the minimum and to prevent reflections. The operating screw is large in diameter and coarse in pitch. The wavelength drum is four inches in diameter, and is easily read. It is adjustable for wavelength and the screw is equipped with stops to prevent accidental disturbance of this adjustment.

III. THE SLITS

Are of the symmetrically moving jaw type, of efficient design, and are completely enclosed. The micrometer screws have adjustable drums, graduated to read to $1/10$ mm slit width. The collimator slit is pro-



*Top view of Mono-
chromator with cover
removed to show ar-
rangement of prisms.*

ected by a quartz window. For purposes of adjustment the telescope slit is fitted with an eyepiece, and a removable fluorescent screen with an index. When these are in position, the instrument serves as a spectrometer, and when they are removed, as a monochromator.

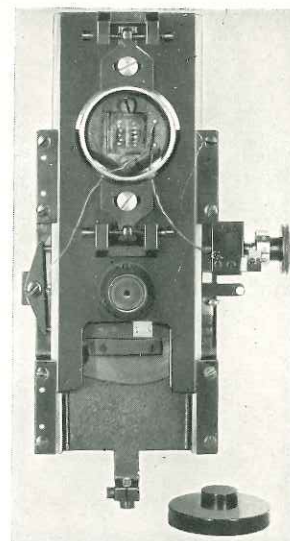
IV. THE TELESCOPES

Are large in diameter and are fitted with diaphragms to suppress stray light. The objectives move along the axis for focusing, and are supported on external slides fitted with rack and pinion carrying focusing drums, which are graduated to read wavelengths. This mechanism is strong and durable. Each objective is of a single piece of quartz, having aspheric curves to correct for aberrations. The definition attained in this way for very high aperture ratio is exceptionally

good, and annoyance from reflections is reduced to the minimum.

Optical Data for Monochromator

Focal Length of Collimator Objective ($\lambda = 5893$)	150.0 mm
Focal Length of Telescope Objective ($\lambda = 5893$)	150.0 mm
Diameter of Collimator and Telescope Lenses	33.0 mm
Angle between Collimator and Telescope	129°
Eyepiece Magnification	14×
Prism Index of Refraction (n_D)	1.5443
Base of Equivalent Sixty Degree Prism	35.2 mm
Range of Monochromator	2000 to 8000 Angstroms
Effective Aperture Ratio	$f:4.0$ for 2000Å and $f:4.9$ for 8000Å
Linear Length of Wavelength Scale	658 mm



*The Thermopile Attachment
with cover removed.*

Thermopile Attachment

For measuring relative spectral energy the Quartz Monochromator may be converted into a direct reading instrument by substituting the thermopile attachment in place of the exit slit.

The thermopile attachment includes an adjustable slit identical with the regular exit slit. Behind it is mounted a slide carrying two alternative means of observation.

In one position an eyepiece with fluorescent screen is brought into line for visually checking the adjustment. In the other position the thermopile is brought directly behind the slit. The thermopile is mounted in an air tight cell which may be evacuated to reduce lag in readings and to increase sensitivity. Adjustments are provided to permit accurate alignment of the thermopile with the exit slit.

A linear thermopile of the Coblenz type is recommended for use with this attachment. Two types are offered, the selection depending on the sensitivity required, one having junctions of copper and constantan, the other of bismuth and silver. The first is the less sensitive, but is more rugged than the second, which is recommended only where the highest sensitivity is required.

Optical Data for 33-86-05 Quartz Ultra-Violet Monochromator

Wavelength (λ)	Prism Index (μ)	Dis- persion $\frac{d\theta}{d\lambda}$	Normal Slit Width (in mm)	Resolving Power (in Å) for Various Slit Widths					
				Nor- mal ×1	Nor- mal ×2	Nor- mal ×4	Nor- mal ×8	Nor- mal ×12	Nor- mal ×20
6563 (C)	1.5419	-288	0.0008	7.70	8.05	9.73	16.90	24.40	34.50
5893 (D)	1.5443	-684	0.0007	2.91	3.04	3.68	6.38	9.24	13.10
4861 (F)	1.5497	-1600	0.0006	1.03	1.08	1.30	2.26	3.25	4.61
4047 (h)	1.5572	-3133	0.0005	0.44	0.46	0.56	0.97	1.38	1.96
3611	1.5635	-4033	0.00045	0.30	0.31	0.38	0.66	0.96	1.36
3034	1.5770	-6985	0.00038	0.15	0.16	0.19	0.33	0.47	0.66
2573	1.5962	-10810	0.00032	0.08	0.08	0.10	0.18	0.25	0.36
2265	1.6182	-16210	0.00028	0.05	0.05	0.06	0.11	0.15	0.21
2099	1.6357	-19375	0.00026	0.04	0.04	0.05	0.09	0.14	0.18
Relative Brightness for Various Slit Widths				1.000	1.902	3.148	3.679	3.789	4.000
Angular Dispersion (8000 to 2000)				7 degrees and 3 minutes					

Catalog No.	Code Word	Specifications
33-86-05	Kaikk	Quartz Monochromator complete as described, in wooden case
33-86-15	Kosof	Thermopile Attachment without thermopile Thermopile, Copper—Constantan } Prices and Specifications Thermopile, Bismuth—Silver } on request

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